DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the block diagram by which the magnetic-disk storage system which carries out this invention was simplified.
[Drawing 2] It is the decomposition perspective drawing of the desirable example of the magnetic-reluctance sensor by the principle of this invention.
[Drawing 3] It is the end view of other desirable examples of the magnetic-reluctance sensor by the principle of this invention.
[Drawing 4] It is the graph which shows the hysteresis curve of the spin bulb MR sensor structure of the conventional technology, and a magnetic-reluctance response.
[Drawing 5] It is the graph which shows the magnetic-reluctance response of MR sensor shown in drawing 2 .
[Drawing 6] It is the schematic diagram showing the spin bulb structure of having positive huge magnetic reluctance.
[Drawing 7] It is the schematic diagram showing the spin bulb structure of having negative huge magnetic reluctance.
[Drawing 8] It is the schematic diagram of the double spin bulb using the positive and negative huge magnetic reluctance by the principle of this invention.
[Drawing 9] It is the decomposition perspective drawing of another desirable example of the magnetic-reluctance sensor by the principle of this invention.
[Drawing 10] It is the end view of another example of the magnetic-reluctance sensor built according to this invention.

[Translation done.]

CLAIMS

[Claim(s)]
[Claim 1] The double spin bulb magnetic-reluctance sensor characterized by providing the following. Substrate. It is formed on the aforementioned substrate and has the 1st, the 2nd, and 3rd ferromagnetic layers separated in the layer of non-magnetic metal, respectively. The ferromagnetic layer of the above 2nd is arranged between the ferromagnetic layer of the above 1st, and the 3rd ferromagnetic layer. The laminated structure which is a parenchyma top perpendicular to the magnetization direction which the magnetization direction was fixed in the above 1st and the 3rd ferromagnetic layer, and the above 1st and the above in the 3rd ferromagnetic layer fixed when the magnetization direction in the ferromagnetic layer of the above 2nd was [an impression magnetic field] zero.
[Claim 2] The magnetic-reluctance sensor according to claim 1 by which each aforementioned ferromagnetic layer is further characterized by having the material layer of at least one addition.
[Claim 3] The magnetic-reluctance sensor according to claim 2 characterized by equipping the aforementioned additional material layer with at least one ferromagnetic nano layer.
[Claim 4] For the aforementioned ferromagnetic layer, the aforementioned nano layer is a magnetic-reluctance sensor according to claim 3 which is the layer of different ferromagnetic material and is characterized by being arranged at the interface between the aforementioned ferromagnetic layer and the aforementioned non-magnetic metal layer.
[Claim 5] The magnetic-reluctance sensor according to claim 1 characterized by having a means to fix the magnetization direction in the above 1st and the 3rd ferromagnetic layer.
[Claim 6] The magnetic-reluctance sensor according to claim 1 by which it has the 1st hard magnetism body whorl which adjoins the ferromagnetic layer of the above 1st, and the 2nd hard magnetism body whorl which adjoins the ferromagnetic layer of the above 3rd, and the above 1st and the 2nd hard magnetism body whorl generate a bias magnetic field in the above 1st and the 3rd ferromagnetic layer, respectively, and are characterized by fixing the magnetization direction in the aforementioned layer by it.
[Claim 7] The magnetic-reluctance sensor according to claim 1 by which it has the following, and the above 1st and the 2nd antiferromagnetic substance layer generate a bias magnetic field in the above 1st and the 3rd ferromagnetic layer, respectively, and are characterized by fixing the magnetization direction in the aforementioned layer by it. The 1st antiferromagnetic substance layer which adjoins the ferromagnetic layer of the above 1st and contacts this. The 2nd antiferromagnetic substance layer which adjoins the ferromagnetic layer of the above 3rd and contacts this.
[Claim 8] The magnetic-reluctance sensor according to claim 1 by which the aforementioned non-magnetic metal layer thickness is characterized by being smaller than the mean free path length of the conduction electron in a sensor.
[Claim 9] The magnetic-reluctance sensor according to claim 1 characterized by the aforementioned magnetization direction in the above 1st and the 3rd ferromagnetic layer aligning by parallel orientation.
[Claim 10] The magnetic-reluctance sensor according to claim 1 characterized by having the coercive force from which the above 1st and the 3rd ferromagnetic layer differ, respectively.
[Claim 11] Have the following, and the aforementioned magnetic-reluctance sensor is formed on a substrate, and is equipped with the 1st, the 2nd, and 3rd ferromagnetic layers separated in the layer of non-magnetic metal, respectively. The ferromagnetic layer of the above 2nd is arranged between the ferromagnetic layer of the above 1st, and the 3rd ferromagnetic layer. The magnetization direction is fixed in the above 1st and the 3rd ferromagnetic layer. the magnetization direction in the ferromagnetic layer of the above 2nd The 1st antiferromagnetic substance layer which adjoins the ferromagnetic layer of a laminated structure and the above 1st which is a parenchyma top perpendicular to the magnetization direction which the above 1st and the above in the 3rd ferromagnetic layer fixed when an impression magnetic field was zero, and contacts this, It has the 2nd antiferromagnetic substance layer which adjoins the ferromagnetic layer of the above 3rd and contacts this. The magnetic storage system by which the above 1st and the 2nd antiferromagnetic substance layer generate a bias magnetic field in the above 1st and the 3rd ferromagnetic layer, respectively, and are characterized by fixing the magnetization direction in the aforementioned layer by it. The magnetic storage medium which has two or more trucks for data logging. The magnetic transducer containing a magnetic-reluctance sensor. The actuator means for being combined with the aforementioned magnetic transducer and moving the aforementioned magnetic transducer to the truck with which it was chosen on the aforementioned magnetic storage medium. The detection means for being combined with the aforementioned magnetic-reluctance sensor and detecting change of the resistance.
[Claim 12] The magnetic storage system according to claim 11 characterized by having an electric lead-wire means for combining the aforementioned magnetic-reluctance sensor with the aforementioned detection means by which it adhered to the aforementioned magnetic-reluctance sensor further on the capping layer to which it adhered on the antiferromagnetic substance layer of the above 2nd, and the aforementioned capping layer.
[Claim 13] The magnetic storage system according to claim 11 characterized by having a means to offer a vertical bias magnetic field, into the activity portion of the aforementioned magnetic-reluctance sensor.
[Claim 14] The magnetic storage system according to claim 11 characterized by the aforementioned magnetization direction in the above 1st and the 2nd ferromagnetic layer aligning at parallel orientation.
[Claim 15] It is formed on a substrate and has the 1st, the 2nd, and 3rd ferromagnetic layers separated in the layer of non-magnetic metal, respectively. The ferromagnetic layer of the above 2nd is arranged between the ferromagnetic layer of the above 1st, and the 3rd ferromagnetic layer. The magnetization direction is fixed in the above 1st and the 3rd ferromagnetic layer. the magnetization direction in the ferromagnetic layer of the above 2nd It is a parenchyma top perpendicular to the magnetization direction which the above 1st and the above in the 3rd ferromagnetic layer fixed when an impression magnetic field was zero. The above 1st and the 2nd ferromagnetic layer form the pair of the 1st

magnetic field. The electric resistance of each set of a ferromagnetic layer, i.e., the 1st layer, the 2nd layer and the 2nd layer, and the 3rd layer changes as a function of the cosine of the angle between the magnetization directions of the two ferromagnetic layers of a pair of. When suitable material including consideration of the resistivity of the material as a function of conduction-electron spin is chosen, it is ineffective to addition-like between two **** and the magnetization direction of a middle free layer rotates in the direction almost parallel to the magnetization direction of the 3rd outside fixed bed from a direction almost parallel to the magnetization direction of the 1st outside fixed bed, the MR sensor by which resistance of a sensor changes from the minimum value to maximum can manufacture. Sensing current is supplied to MR sensor from a current source, and MR sensor generates the voltage drop which is proportional to change of resistance of MR sensor by rotation of the magnetization direction in the inside of a middle ferromagnetic free layer as a function of the impression external magnetic field sensed among the ends of a reading element.

[0010] In the 2nd desirable example of this invention, the magnetization direction in two outside ferromagnetic layers is parallel, and a multilayer spin bulb sensor perpendicular to the magnetization direction in a middle ferromagnetic free layer is both offered.

[0011]

[Example] Probably, this invention will be clear although it is described as what is carried out in a magnetic-disk storage system as shown in drawing 1 . [applicable to other magnetic-recording systems, such as a magnetic tape record system, for example] The magnetic disk 12 which can rotate at least one piece is supported on a spindle 14, and rotates with the disk drive motor 18. The magnetic-recording medium on each disk takes the form of the annular pattern of this cardiac data track (not shown) of a disk 12.

[0012] At least one slider 13 is positioned on a disk 12, and each slider 13 supports one or more R/W converters 21 (usually called the read-write head). When a disk rotates, a slider 13 moves the disk front-face 22 top to radial in and abroad, and can access a head 21 by it at various portions of the disk with which desired data are recorded. Each slider 13 is attached in the actuator arm 19 by the suspension 15. A suspension 15 induces few spring force and a slider 13 is forced on the disk front face 22 by it. Each actuator arm 19 is attached in the actuator means 27. An actuator means is good at a voice coil motor (VCM), as shown in drawing 1 . VCM is controlled by the motor current signal to which the direction and speed of movement of a coil are supplied from a control unit including the coil which can move within a fixed field system.

[0013] By working [of a disk-memory system], and rotation of a disk 12, air bearing occurs between a slider 13 and the disk front face 22, and this applies the upward force to a slider. In this way, few spring force of a suspension 15 is negated and, as for air bearing, only the interval of small simultaneously regularity raises a slider 13 up from a working disk front face.

[0014] Various components of a disk-memory system are controlled by the control signal generated with the control units 29, such as working, an access-control signal, and an internal clock signal. Usually, a control unit 29 contains for example, a logic-control circuit, a storage means, and a microprocessor. A control unit 29 generates the control signal for controlling various system operation, such as a drive-motor control signal on a line 23, and a head position / seeking control signal on a line 28. In order that the control signal on a line 28 may move the the best for the data track of the request on the related disk 12 and may align the selected slider 13, it offers a desired current profile. A reading signal and a write-in signal communicate between the read-write heads 21 by the record channel 25.

[0015] Illustration of drawing 1 which accompanies the above-mentioned description of a typical magnetic-disk storage system and it is only a thing for instantiation. It will be in Ming that a disk-memory system can include many disks and actuators, and each actuator can support some sliders.

[0016] ** [reference of drawing 2 / contain / the 1st ferromagnetic thin film layer 31, the 1st non-magnetic metal thin film layer 33, the 2nd ferromagnetic thin film layer 35, the 2nd non-magnetic metal thin film layer 37, and the 3rd ferromagnetic thin film layer 39 / the desirable example of the MR sensor 30 by the principle of this invention / next,] The magnetization direction of two outside ferromagnetic layers 31 and 39 makes the angle of about 90 degrees to the magnetization direction of the middle ferromagnetic layer 35, when there is no external impression magnetic field which is parallel, i.e., the same direction, and is shown by arrows 32, 34, and 38, respectively mutually. Pin fixing [that is,] and attachment [the magnetization direction of the 1st and 3rd ferromagnetic outside layers 31 and 39] furthermore in the desirable direction shown by arrows 32 and 38 That is, although the magnetization direction of the outside ferromagnetic layers 31 and 39 is being fixed, as the arrow 34 of the dashed line on a layer 35 shows to drawing 2 , the magnetization direction of the middle ferromagnetic layer 35 answers an external (it is (like magnetic field h shown in drawing 2)) impression magnetic field, and is rotated freely.

[0017] According to this desirable example of this invention, the ferromagnetic layers 31, 35, and 39 can be manufactured from those alloys, such as the suitable magnetic substance, such as cobalt (Co), iron (Fe), and nickel (nickel), and a ferronickel (NiFe), nickel cobalt (NiCo), and iron cobalt (FeCo). The non-magnetic metal spacer layers 33 and 37 contain other suitable noble metals, such as copper (Cu) or silver (Ag), and gold (Au), or the alloy of those. MR sensor based on the spin bulb effect that the reading element of a sensor contains the laminated structure of a ferromagnetic / non-magnetic material / ferromagnetic is indicated in detail by the above-mentioned U.S. patent application 07th / No. 625343, and builds this specification into this specification by quotation. Exchange bias can be applied to the outside fixed ferromagnetic layers 31 and 39 by the layer (shown in drawing 9) of the antiferromagnetic substance, such as for example, adjoining iron manganese (FeMn). MR sensor based on the spin bulb effect that a fixed ferromagnetic layer receives exchange bias by the adjoining antiferromagnetic substance layer is indicated in detail by the above-mentioned U.S. patent application 07th / No. 937620, and builds this specification into this specification by quotation. The material which uses the adjoining hard magnetism layer as an exception method, or has coercive force high enough in the outside fixed beds 31 and 39 can be used, and the magnetization direction of the fixed ferromagnetic layers 31 and 39 can also be fixed.

[0018] The structures of the single spin bulb MR sensor of a conventional type which is indicated by many above-mentioned patent application are free FM/NM / fixed FM/AFM fundamentally. However, free FM and Fixation FM are the ferromagnetic layers separated by the non-magnetic layer NM. The magnetization direction of a fixed FM layer is fixed to the magnetic field of a certain amount of size by the switched connection bias magnetic field brought about by the antiferromagnetic substance layer AFM. The conduction electron which moves to other FM layers is scattered about according to the spin from FM layer which has passed along NM layer, and the magnetoresistance effect of this sensor is based on resistance of a sensor increasing, when the magnetization directions in adjoining FM layer differ. It is the function of the cosine of the angle between the magnetization directions in FM layer, change of

---

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] this invention relates to the advanced magnetic-reluctance read sensor which provides a sensor with a fixed-bias magnetic field using multilayer double spin bulb structure and antiferromagnetism switched connection in more detail about the magnetometric sensor for reading the information signal generally recorded on the magnetic medium.
[0002]
[Description of the Prior Art] With the conventional technology, the magnetic reading converter called a magnetic-reluctance (MR) sensor or head is indicated, and it turns out that this can read data in a magnetic front face by big alignment density. MR sensor detects a magnetic field signal through change of the resistance as the strength of magnetic flux, and a function of a direction sensed by the reading element. the cosine of the angle between the magnetization direction and the direction of sensing current which flows the inside of an element is square(cos2)-alike, and, as for MR sensor of such conventional technology, one component of resistance of a reading element operates based on the anisotropy magnetic-reluctance (AMR) effect of changing proportionally the AMR effect -- depending -- detailed explanation -- paper [, such as D.A Thompson (Thompson),]" -- Memory, Storage, and and Related Applications"IEEE It has appeared in Trans.Mag.MAG-11 and p.1039 (1975).
[0003] Furthermore, the more remarkable magnetoresistance effect returned to spin dependency dispersion by the layer interface to which change of resistance of a laminating magnetometric sensor accompanies spin dependency transmission of the conduction electron between the magnetic layers through a non-magnetic layer and it is indicated recently. This magnetoresistance effect is called by various names, such as the "huge magnetic-reluctance" effect and the "spin bulb" effect. Sensitivity is improved and such a magnetic-reluctance sensor has a large change of resistance rather than it is made of a suitable material and is observed by the sensor using the AMR effect. By this kind of MR sensor, the flat-surface internal resistance between one pair of ferromagnetic layers separated by the non-magnetic layer changes in proportion to the cosine (cos) of the angle between the magnetization directions of two layers.
[0004] The laminating magnetism structure of bringing high MR hardening produced by anti-parallel alignment of the magnetization in a magnetic layer to U.S. Pat. No. 4949039 is indicated. Although ferromagnetic transition metals and a ferromagnetic alloy are mentioned in the above-mentioned specification as a possible material used by the laminated structure, a desirable material superior to MR signal amplitude's is not shown. Obtaining anti-[from which antiferromagnetism die-change combination was anti-used further and the layer of an adjoining ferromagnetic was separated in the thin internal layer of chromium (Cr) or an yttrium (Y)] parallel alignment is indicated by this specification.
[0005] Resistance between two uncombined ferromagnetic layers changes to the U.S. patent application 07th of a simultaneous connection for which it applied on December 11, 1990 and which was transferred to these people / No. 625343 in proportion to the cosine of the angle between the magnetization directions of two layers, and MR sensor independent of the direction of the current passing through the inside of a sensor is indicated. When a fixed material is combined, this mechanism generates bigger magnetic reluctance than AMR, and is called huge magnetic reluctance or "spin bulb (simian virus)" magnetic reluctance.
[0006] To the U.S. patent application 07th of a simultaneous connection for which it applied on August 28, 1992 and which was transferred to these people / No. 937620 Including the thin film layer of two ferromagnetics separated in the thin film layer of non-magnetic metal material, when an external impression magnetic field is zero, MR sensor based on the above-mentioned effect that magnetization of one ferromagnetic layer is kept perpendicular to the ferromagnetic layer of another side by switched connection with the adjoining antiferromagnetic substance layer is indicated.
[0007]
[Problem(s) to be Solved by the Invention] By the above single spin bulb MR sensors, conduction electron is not only scattered about toward the 2nd ferromagnetic layer to which the magnetization direction is being fixed, but is scattered about also in the direction which separates from the opposite direction, i.e., the 2nd ferromagnetic layer, from the 1st ferromagnetic layer to which the magnetization direction is not being fixed. Since what is contributed to the magnetoresistance effect is only conduction electron scattered about between two ferromagnetic layers, the conduction electron scattered on opposite direction will become useless. Therefore, the purpose of this invention is to offer MR sensor which can also use the conduction electron scattered on which direction.
[0008]
[Means for Solving the Problem] According to the principle of this invention, the magnetic-reluctance (MR) reading sensor which has multilayer double spin bulb structure brings about big MR response by the low impression magnetic field. This MR structure is formed on a suitable substrate, and contains the laminated structure equipped with the 1st, the 2nd, and 3rd ferromagnetic thin film layers separated in the thin film layer of non-magnetic metal material. As for the 1st and 3rd ferromagnetic layer, i.e., the layer of the outside of structure, the magnetization direction is fixed, the 2nd middle layer of structure is a soft magnetism, and the magnetization direction is a parenchyma top perpendicular to the magnetization direction of two outside ferromagnetic layers. "Pin attachment" [the magnetization direction of the 1st and 3rd ferromagnetic layers] [with some methods containing the hard bias or exchange bias by the adjoining antiferromagnetic substance layer known for this technical field] [be / it / that is, / fixable and]
[0009] In the desirable example, as for two outside ferromagnetic layers, the magnetization direction is being mutually fixed by anti-parallel, therefore each fixed bed carries out the work holding the magnetic flux of the fixed bed of another side. The magnetization direction of the 2nd middle ferromagnetic layer can be freely rotated by the impression

ferromagnetic layer which has positive huge magnetic reluctance in the meantime, and was divided into it by the non-magnetic layer. The magnetic-reluctance sensor equipped with a laminated structure by which the above 2nd and the 3rd ferromagnetic layer form the pair of the 2nd ferromagnetic layer which has negative huge magnetic reluctance in the meantime, and was divided into it by the non-magnetic layer.
[Claim 16] The magnetic-reluctance sensor according to claim 15 characterized by the aforementioned magnetization direction in the above 1st and the 3rd ferromagnetic layer aligning at the orientation of anti-parallel.
[Claim 17] The magnetic-reluctance sensor according to claim 15 by which it has the following, and the above 1st and the 2nd antiferromagnetic substance layer generate a bias magnetic field in the above 1st and the 3rd ferromagnetic layer, respectively, and are characterized by fixing the magnetization direction in the aforementioned layer by it. The 1st antiferromagnetic substance layer which adjoins the ferromagnetic layer of the above 1st and contacts this. The 2nd antiferromagnetic substance layer which adjoins the ferromagnetic layer of the above 3rd and contacts this.
[Claim 18] The magnetic-reluctance sensor according to claim 17 characterized by having the blocking temperature from which the above 1st and the 2nd antiferromagnetic substance differ.
[Claim 19] Furthermore, the magnetic-reluctance sensor according to claim 15 characterized by including a means to fix the magnetization direction in the above 1st and the 3rd ferromagnetic layer.
[Claim 20] The magnetic-reluctance sensor according to claim 19 by which it has the 1st hard magnetism body whorl which adjoins the ferromagnetic layer of the above 1st, and the 2nd hard magnetism body whorl which adjoins the ferromagnetic layer of the above 3rd, and the above 1st and the 2nd hard magnetism body whorl generate a bias magnetic field in the above 1st and the 3rd ferromagnetic layer, respectively, and are characterized by fixing the magnetization direction in the aforementioned layer by it.
[Claim 21] The magnetic-reluctance sensor according to claim 15 by which it has the following, and the above 1st and the 2nd antiferromagnetic substance layer generate a bias magnetic field in the above 1st and the 3rd ferromagnetic layer, respectively, and are characterized by fixing the magnetization direction in the aforementioned layer by it. The 1st antiferromagnetic substance layer which adjoins the ferromagnetic layer of the above 1st and contacts this. The 2nd antiferromagnetic substance layer which adjoins the ferromagnetic layer of the above 3rd and contacts this.
[Claim 22] The magnetic-reluctance sensor according to claim 15 characterized by including the ferromagnetic which has the coercive force from which the above 1st and the 3rd ferromagnetic layer differ, respectively.

[Translation done.]

this resistance is the minimum when the magnetization directions are parallel, i.e., the same direction, and when the magnetization directions in a layer are anti-parallel, i.e., an opposite direction, it serves as the maximum.
[0019] However, with the above-mentioned single spin bulb structure, conduction electron is not only scattered about toward a fixed FM layer from a free FM layer, but is scattered about also in the direction which separates from a fixed FM layer to an opposite direction. Therefore, only the portion scattered about between two FM layers among conduction electron contributes to the magnetoresistance effect of a sensor.
[0020] The structure mentioned above about drawing 2 contains the "duplex" spin bulb to which it is doubled by spin bulb structure with the symmetrical form about the free FM layer. The structures of a double spin bulb are AFM1/the fixed FM1/NM1/free FM/NM2/fixation FM2/AFM2, and bring about two pairs of FM layers separated in NM layer. By this, use of the conduction electron scattered on both directions from a middle free FM layer is attained. The direction of the magnetization in two outside fixation FM is fixed by the antiferromagnetic substance layers AFM1 and AFM2 which adjoin, respectively, and the magnetization direction in a free FM layer answers an impression magnetic field, and can be rotated freely.
[0021] Next, reference of drawing 3 shows the end view of the drawing 2 and the double spin bulb sensor described about 9 and 10 by which the ferromagnetic layers FM1, FM2, and FM3 contain two or more ferromagnetic layers, respectively. As mentioned above, a double spin bulb sensor includes FM1/S1/FM2/S2/FM3 structure. In this example, the 1st ferromagnetic layer FM 1 is called the layer 311 of the 1st ferromagnetic, such as NiFe, and "nano layer", for example, contains the layer 313 of the 2nd ferromagnetic, such as Co. The interface of the 1st ferromagnetic layer FM 1 and the 1st spacer layer 371 adheres to the nano layer 313 of the 2nd ferromagnetic. Therefore, the 1st ferromagnetic layer forms the bilayers 311 and 313 of two sorts of different ferromagnetics. Similarly, as for the 3rd ferromagnetic layer FM 3, the nano layer 303 is formed in the interface of the 3rd ferromagnetic layer FM 3 and the 2nd spacer layer 331 including the bilayers 301 and 303 of two sorts of different ferromagnetics. Since the 2nd middle ferromagnetic layer FM 2 forms an interface with both spacer layers 331 and 371, it formed for example, contains three layers with the nano layers 309 and 307 of the 2nd ferromagnetic, such as Co, in the interface of the ferromagnetic layer 305 of centers, such as NiFe, and the spacer layers 371 and 331 of respectively contiguity, for example. The range of nano layer thickness is 0.5-20A. As an exception method, a nano layer can also be formed in the interior of a ferromagnetic layer from the interface of a ferromagnetic layer and a spacer layer in the place of Distance X. When you form a nano layer in the interior of a ferromagnetic layer, let material of a nano layer be a ferromagnetic at non-magnetic materials, such as Cr, and a row. It applies on August 26, 1991 and the magnetic-reluctance sensor which used the above-mentioned nano layer is indicated in detail by the U.S. patent application 07th of a simultaneous connection transferred to these people / No. 750157. The indication is included in this specification by quotation.
[0022] Next, reference of drawing 4 and 5 indicates the magnetic-reluctance properties of the double spin bulb MR sensor by this invention to be the magnetic-reluctance curve 36 of the single spin bulb MR sensor of a conventional type, and a hysteresis curve 46, respectively for comparison. As shown in drawing 4 , the spin bulb sensor of the kind indicated by the above-mentioned U.S. patent application 07th / No. 937620 Adhere on (Silicon Si) substrate and it has the structure of Si/50Ta/75NiFe/22.5Cu/50NiFe/110FeMn/50Ta. Although the number in an upper formula shows the thickness of an Angstrom unit and two tantalum (Ta) layers function as a buffer coat and a capping layer, respectively, 4% of maximum reluctivity **R/R is brought about. The thickness of each class is optimized so that the highest magnetic-reluctance value acquired with many material in this structure may be brought about.
[0023] On the other hand, as shown in drawing 5 , it adheres to the example with a desirable double spin bulb on Si substrate, it has the structure of Si/50Ta/20NiFe/110FeMn/60NiFe/25Cu/100NiFe/25Cu/60NiFe/110FeMn/50Ta, and brings about 5.5% of reluctivity higher 35% than single spin bulb structure. The 1st NiFe layer in the above-mentioned double spin bulb structure offers the seed layer used in order to acquire the crystal structure required to bring about the antiferromagnetic substance FeMn. It has sufficient high resistivity to suppress current branching to the minimum, and if it is the material into which FeMn of an antiferromagnetism form is grown up, is suitable for using anything as a seed layer.
[0024] Next, if drawing 6 , and 7 and 8 are referred to, the double spin bulb MR sensor by which the magnetization direction in an outside fixed ferromagnetic layer is mutually maintained by anti-parallel, i.e., an opposite direction, can be designed. Furthermore, **R / R value of the sensor of a high value are generable by choosing the material of each class appropriately using the spin dependency magnetic reluctance of positive [which is called huge magnetic reluctance (GMR)] and negative both. As shown in drawing 6 , both spin rise resistance (rhoup) of a ferromagnetic layer and spin down resistance (rhodown) fill related rhoup>rhodown or rhoup<rhodown including two ferromagnetic layers FM1 and FM2 from which the single spin bulb structure of having GMR of a positive sensor was separated by the non-magnetic layer NM. With this structure, resistance serves as the minimum, when the magnetization direction of the layers FM1 and FM2 shown by the arrow 50 is parallel, and when the magnetization directions of layers FM1 and FM2 are anti-parallel, it serves as the maximum. As shown in drawing 7 , the single spin bulb structure of having negative GMR has two ferromagnetic layers separated by the non-magnetic layer, and is rhoup<rhodown in rhoup>rhodown and the 2nd ferromagnetic layer FM 2 in the 1st ferromagnetic layer FM 1. With this structure, resistance serves as the minimum, when magnetization aligns at anti-parallel, as an arrow 60 shows, and when magnetization aligns in parallel, it serves as the maximum.
[0025] For example, drawing 8 shows three ferromagnetic layers by this invention. Among layers FM1 and FM2, GMR is positive, and when those magnetization shown by arrows 71 and 73 aligns in parallel, it produces the minimum resistance. On the other hand, among layers FM2 and FM3, GMR is negative, and when those magnetization shown by arrows 73 and 75 aligns at anti-parallel, it produces the minimum resistance. since it is fixed to the opposite direction (arrows 71 and 75), when magnetization of the free layer FM 2 shown by the arrow 73 aligns as an effect of the net of this structure at magnetization and parallel of the fixed bed FM 3 shown by the arrow 75, resistance becomes the maximum, and the magnetization direction of layers FM1 and FM3 becomes the minimum when magnetization of the free layer FM 2 aligns at magnetization and parallel of the fixed bed FM 1 shown by the arrow 71 Furthermore, since magnetization of FM1 and FM3 of the two fixed beds aligns to an opposite direction, each class carries out the work holding the magnetic flux of the layer of another side, and the demagnetization effect of the fixed bed decreases by it.
[0026] ** [reference of drawing 9 / contain / the 1st antiferromagnetic substance thin film layer 51, the 1st ferromagnetic thin film layer 41, the 1st non-magnetic metal thin film layer 43, the 2nd ferromagnetic thin film layer 45, the 2nd non-magnetic material thin film layer 47, the 3rd ferromagnetic thin film layer 49, and the 2nd antiferromagnetic substance thin film layer 53 / another desirable example of the MR sensor 40 by the principle of this invention / next,] Two antiferromagnetic substance layers 51 and 53 bring about a bias magnetic field into the adjoining ferromagnetic

layer 41 and 49 by well-known switched connection by this technical field, respectively. The magnetization directions of two outside ferromagnetic layers 41 and 49 shown by arrows 42 and 48, respectively are anti-parallel, i.e., an opposite direction, mutually, and when there is no external impression magnetic field, they have the angle of about 90 degrees to the magnetization direction of the middle ferromagnetic layer 45 shown by the arrow 44. Furthermore, the magnetization direction of the 1st and 3rd outside ferromagnetic layers 41 and 49 is being fixed in the desirable direction shown by arrows 42 and 48 by the exchange bias of the antiferromagnetic substance layers 51 and 53, respectively.

[0027] As for the exchange bias layers 51 and 53, in this desirable example, it is desirable that FeMn and nickel manganese (NiMn) are included, respectively, including the different antiferromagnetic substance. Blocking temperature differs, therefore these two antiferromagnetic substance can set up independently the direction of exchange bias of each antiferromagnetic substance layers 51 and 53 mutually. For example, in FeMn and NiMn, the blocking temperature of FeMn is about 220 degrees C, and the blocking temperature of NiMn is much higher than it. Therefore, the direction of exchange bias of a NiMn layer is first set up at comparatively high temperature, for example, about 260 degrees C, and subsequently, the direction of exchange bias of a FeMn layer is lower than it, and it is set up at temperature with whether high it is small, for example, about 230 degrees C, rather than the blocking temperature of FeMn. As discussed above, a seed layer is used, and the antiferromagnetic substance layers 51 and 53 can have desired structure. In order to offer the sensor which produces the value of high magnetic reluctance, the material of the ferromagnetic layers 41, 45, and 49 is chosen so that both positive and negative GMR **** can be used. As drawing 7 was described previously, between the 1st ferromagnetic layer 41 and the 2nd ferromagnetic layer 45, GMR serves as positive, and between the 2nd ferromagnetic layer 45 and the 3rd ferromagnetic layer 49, material is chosen so that GMR may become negative. The dilution alloy which contains vanadium (V) or chromium (Cr) in nickel or Fe substrate brings about the ferromagnetic used as rhoup>rhodown, and Fe or Co in nickel substrate brings about the ferromagnetic used as rhoup<rhodown. Spin dependency resistance of Fe or Co diluted with aluminum (aluminum), iridium (Ir), or manganese is also known. The nonmagnetic spacer layers 43 and 47 can make Cu, Au, Ag, etc. suitable non-magnetic metal. As for the thickness of the antiferromagnetic substance layers 51 and 53, it is desirable that it is 50 or 200A.

[0028] Next, reference of drawing 10 shows still more nearly another example of the double spin bulb MR sensor by this invention. Before adhering the 1st antiferromagnetism exchange bias layer 59, the suitable lower layers 57, such as Ta, Ru, and CrV, are adhered on a substrate 55. The purpose of a lower layer 57 is optimizing the texture of many consecutiveness layers, grain size, and a gestalt. A gestalt may be very important for acquiring the big MR effect property of single spin bulb structure. It is because it will become possible to use the very thin non-magnetic metal spacer layers 63 and 65 among the ferromagnetic layers 61, 65, and 69 if it does so. A lower layer must have high resistivity again, in order to suppress the current branching effect to the minimum. When the substrate 55 is made of a material of resistivity high enough and has a front face flat enough and suitable crystallography-structure, a lower layer 57 can be omitted. FeMn, NiMn, etc. can be used for the exchange bias layer 59 anything, if it is the suitable antiferromagnetic substance. If FeMn (60/40 % of the weight) is used, when specifically adhering a FeMn antiferromagnetic substance layer first, the joint magnetic field between two consecutive ferromagnetic layers decreases. When it cannot adhere directly so that the material used for the 1st antiferromagnetic substance layer 59 may have the suitable crystal structure, a seed layer (not shown) may also be needed. For example, in order to obtain FeMn of an antiferromagnetism form when using FeMn for an exchange bias layer as discussed above, the seed layer of NiFe or AuCu is preferably desirable.

[0029] The 1st ferromagnetic thin film layer 61, the 1st non-magnetic metal thin film layer 63, the 2nd ferromagnetic thin film layer 65, the 2nd non-magnetic metal thin film layer 67, the 3rd ferromagnetic thin film layer 69, and the 2nd antiferromagnetic substance thin film exchange bias layer 71 are adhered on a lower layer 57. The magnetization direction of the 1st and 3rd ferromagnetic layers 61 and 69 is parallel to mutual, and when there is no impression magnetic field, the angle of about 90 degrees is made to the magnetization direction of the 2nd middle ferromagnetic layer 65. As mentioned above, a position is fixed by the bias magnetic field which generated the magnetization direction of the 1st and 3rd ferromagnetic layers 61 and 69 by switched connection. The outside ferromagnetic layers 61 and 69 are fixable by using an adjoining hard magnetism layer, or using a comparatively high material of coercive force for an outside ferromagnetic layer as an exception method, and setting up the magnetization direction during manufacture. When it is anti-parallel, in order for the magnetization directions of the outside ferromagnetic layers 61 and 69 to differ, for example, for the magnetization direction of one layer to be able to set up independently of the layer of another side, the coercive force of each class must differ.

[0030] The suitable magnetic substance, such as Co, Fe, and nickel, or NiFe, NiCo, FeCo, etc. can manufacture the ferromagnetic layers 61, 65, and 69 from those alloys. The thickness of the ferromagnetic layers 61, 65, and 69 can be chosen in about 5-150A.

[0031] As for the nonmagnetic spacer layers 63 and 67, it is desirable that it is the metal of high conductivity. Noble metals, such as Au, Ag, and Cu, give big MR response, Pt and Pd give small MR reaction, and Cr and Ta show very small MR response. The thickness of the nonmagnetic spacer layers 63 and 67 is smaller than the mean free path of the conduction electron in a sensor, and it is desirable to choose in about 10-40A.

[0032] Next, on MR sensor, the capping layers 73 of high electrical resistance materials, such as Ta and a zirconium (Zr), are adhered. Lead wire 76 is formed and a circuit path is formed between MR sensor, a current source 77, and the sensing means 79. Furthermore, in order to suppress a Barkhausen noise to the minimum, it is desirable to offer a vertical bias magnetic field parallel to lengthwise [of the magnetic layer in a sensor]. If the layer 75 of a suitable hard magnetism object is adhered on the edge field of a sensor as everyone knows in this technical field, a vertical bias magnetic field will be formed by the active region 78 of the center of a sensor. A vertical bias magnetic field can also be formed by the switched connection by the antiferromagnetic substance layer which contacted a ferromagnetic layer and directly and was made to form on the edge field of a sensor as an exception method.

[0033]

[Effect of the Invention] According to this invention, the conduction electron scattered on both directions towards an outside ferromagnetic layer from a middle ferromagnetic layer can be used.

[Translation done.]